SOIL CHANGES AS THEY AFFECT WATER-LOGGING AND DRAINAGE

(TENTATIVE)

By

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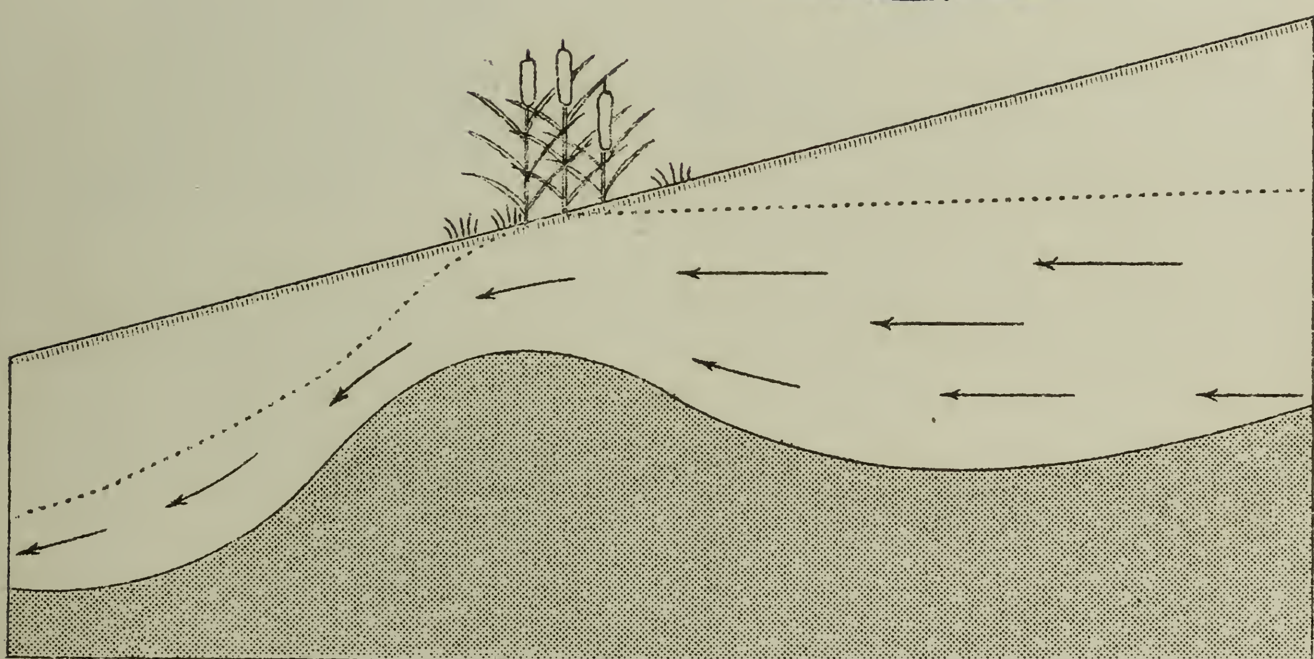
Drainage Engineer



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SUMMARY

Approximately 90 per cent of the isolated individual farm drainage problems in the West today can be attributed to soil changes. These soil changes cause drainage problems that range all the way from slightly crop injurious, to bogs, springs and complete crop failures. Water-logging due to soil changes may effect a tenth of an acre or many thousands of acres depending upon the type and extent of the soil change. Harmful surface deposits of saline or alkaline elements often accompany water-logging in many areas.

Although interception drains may be the best method of handling this problem, one interception drain may not be adequate to solve all the drainage problems caused by soil changes. For some problems a grid system or a number of drains may be required.

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INTRODUCTION

The objective of this publication is to outline and describe methods for investigating the general farm drainage problem. A majority of these drainage problems are caused by changes in soil permeability which interfere with the movement of water through the soil. These drainage problems can generally be best solved after making a soils investigation to a depth of 10 feet and analyzing the soil logs for changes in permeability.

The techniques as described herein have been developed from the results of field drainage investigations and are adapted to fit the needs of the field technicians.

SURFACE CHARACTERISTICS OF SOIL CHANGES

Soil changes are frequently characterized by abrupt areas of water-logged land or crop damage. This abrupt water-logging may occur on uniform flat slopes, at breaks in grade, or on very steep slopes. The affected area may be narrow and extend for several miles. It may be a large area of many acres, of it may be a small bog. It is often possible to determine a definite water-logged pattern of an area from aerial photographs. In many areas, the water-logging may be accompanied by harmful deposits of saline or alkaline elements.

Water-logging due to soil changes occur where a soil stratigraphy changes from a more to a less permeable profile. These soil changes

may be but slight, changing from a sandy loam to a silt loam, or they may be great and change from a coarse sand and gravel to a slowly permeable clay. Outstanding examples of water-logging, due to soil changes, frequently occur on fairly steep slopes when the soil changes are great.

An artificial "soil change" may be developed when the soil profile, or parts of the profile become strongly alkaline. Alkali generally breaks down the structure of a soil and may effectively lower the permeability of a sandy loam to that of a silt loam or even slower.

When water moves up from an artesian aquifer and water-logs the surface soil profile it sometimes forms a water-dam or mound. Ground water from up-slope moves down against the water-dam, and slowly builds up and water-logs the soil upstream from the dam. This water-logged area may extend for a mile or so above the dam depending upon the slope of the land, the permeability of the soil, and the amount of ground water moving down slope.

INVESTIGATION

A drainage investigation of soil changes has been broken down into the following steps.

1. Topographic investigation.
2. Soils investigation.
3. Alkali investigation.
4. Water table investigation.
5. Water source investigation.

These factors are not necessarily placed in order of importance, however, they are given in a logical field sequence. Some of the steps can be very brief depending upon the type and severity of the problem.

Topographic investigation.

The topographic investigation can usually be made very rapidly - even visually in most cases. The important visual observations to make are general slope, low areas and break in grade. If a more accurate survey is needed a hand level or instrument can be used.

Soils investigation.

The soil-strata-survey is the most important step and generally gives a key to the water-logging problems. A survey is made to determine the location, extent and physical characteristics of the various underlying soil layers. There is no definite depth to which the survey should be made. For some problems, the causes of water-logging may be solved with a five foot survey and on others a 20 foot or deeper survey may be required. One or two lines of holes over the problem area will generally locate the soil change and give a clue to the water-logging.

A suggested boring location layout for the more general problems is presented in Figure 1.

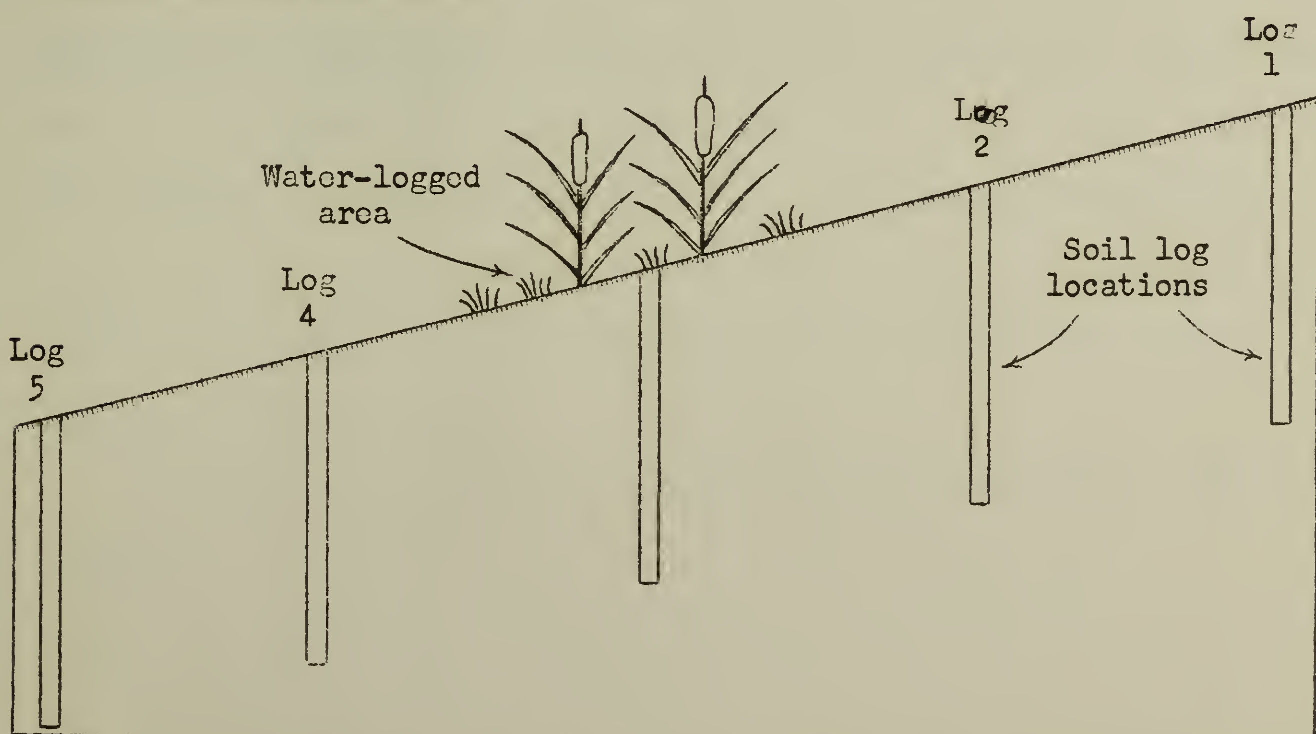

Figure 1. Suggested soil log locations for water-logged areas.

The suggested soil log layout should generally bracket the problem area. Following analysis of these initial soil logs, subsequent holes can be located to obtain additional information if it is needed to determine the type and degree of soil change.

The holes should be carefully logged and filed for future references. A suggested Soil Profile Chart for drainage investigations is shown as Figure 2. The soil strata are recorded on the chart by drawing a vertical line at the respective number that corresponds to the soil texture legend at the upper right hand corner of the Soil Profile Chart. For example, the soil strata at a depth of 8 to 8.6 feet was classified as a silt loam. The silt loam strata was recorded by drawing a vertical line under column 4 on the Soil Profile Chart.

The soils are logged with respect to permeability as well as texture. For example, some clay strata may have a high permeability due to fractures or cracks and some sand strata may have a low permeability due to compaction or cementation. These strata whose permeability varys from the texture legend, are recorded by cross hatch lines on the chart. For example, a strata at a depth of 1 to 2 feet was classified as a coarse sand and fine gravel in a sandy loam matrix. The strata is recorded on the chart by cross-hatching the area between the 6 and 9 columns for those depths.

Permeability estimates as broadly related to texture are given in Table 1.

U. S. DEPARTMENT OF AGRICULTURE
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SOIL PROFILE CHART

For Drainage Investigations

1 - Clay
2 - Silty clay loam
3 - Clay loam
4 - Silt loam
5 - Loam
6 - Sandy loam
7 - Loamy fine sand
8 - Sand
9 - Coarse sand and fine gravel
10 - Coarse gravel
11 - Cobble

Property John Quizdowski

Boring No. 1 Land Use Waste Crop Condition very Poor

Technician GBB Date Survey 6/5/53 Symbol

Depth in Feet	Texture	Special Features
0.0		pH 9.4 Wet pH 9.3
1.0	Loam and Coarse sand	pH 9.0 Free Water
2.0		pH 9.1
3.0		pH 8.3
4.0		Old Tulle roots
5.0		
6.0	Silt & sand	pH 8.8
7.0		pH 8.3 few small rocks
8.0		pH 8.5 very Impermeable
9.0		pH 9.1

Permeability: Slow (1, 2) — Moderate (3, 4, 5) — Rapid (6, 7, 8) — Very Rapid (9, 10, 11)

Table 1. Index numbers, soil textures and coefficients of permeability.

Index	Texture	Approximate Coefficient of Permeability		
		In./Hr.	$cc/cm^2/Hr.$	$Gal/ft^2/day$
11	Cobble	4000+	10,000+	50,000+
10	Coarse gravel	4000	10,000	50,000
9	Coarse sand & fine gravel	2000	5,000	25,000
8	Sand	20	50	250
7	Loamy fine sand	2	5	25
6	Sandy loam	0.4	1	5
5	Loam	0.06	0.2	0.5
4	Silt loam	0.04	0.1	0.5
3	Clay loam	0.03	0.07	0.4
2	Silty clay loam	0.02	0.05	0.25
1	Clay	below 0.004	below 0.01	below 0.05

In./Hr = Inches per hour.
$cc/cm^2/Hr.$ = Cubic centimeters per square centimeter per hour.
$Gal/ft^2/day$ = Gallons per square foot per day.

Field checks on various soil strata to determine their permeability and location with respect to Table 1 can be obtained by various methods such as the Falling Head Permeameter (1).[1/] These checks can be made in the field or in the laboratory, and are suggested as an aid in classifying the soils.

Alkali investigation.

The alkali investigation should be conducted in conjunction with the soils investigation. As the soil log holes are dug, a sample of the various strata should be placed in a spot plate and the pH obtained using color indicators (2). These pH valves should be recorded on the soil log sheets in the "Special Features" column on the line opposite the sample depth.

1/ Refers to "Literature Cited" at end of report.

Water table investigation.

An initial water table investigation should be made by measuring the depth of water in the soil log holes and recording this level on the Soil Profile Chart. Time should be allowed for the ground water to reach a static level in the auger hole prior to measuring.

Water source survey.

The water source survey is made to detect any horizontal or vertical movement of ground water at or in the vicinity of the problem area. The ground water hydraulic gradient can be obtained from additional auger holes dug above and below the problem area. Horizontal movement of ground water can be detected by slope of the hydraulic gradient. Differential length piezometers (3) can be installed in the problem area to detect any vertical movement of ground water.

A more detailed and precise investigation may be required for the more complex and difficult drainage problem areas. Procedure for such an investigation is suggested in Technical Bulletin No. 1065. (4).

Typical soil changes.

The following figures are examples of typical soil changes and soil blocks.

Offshore clay bar.

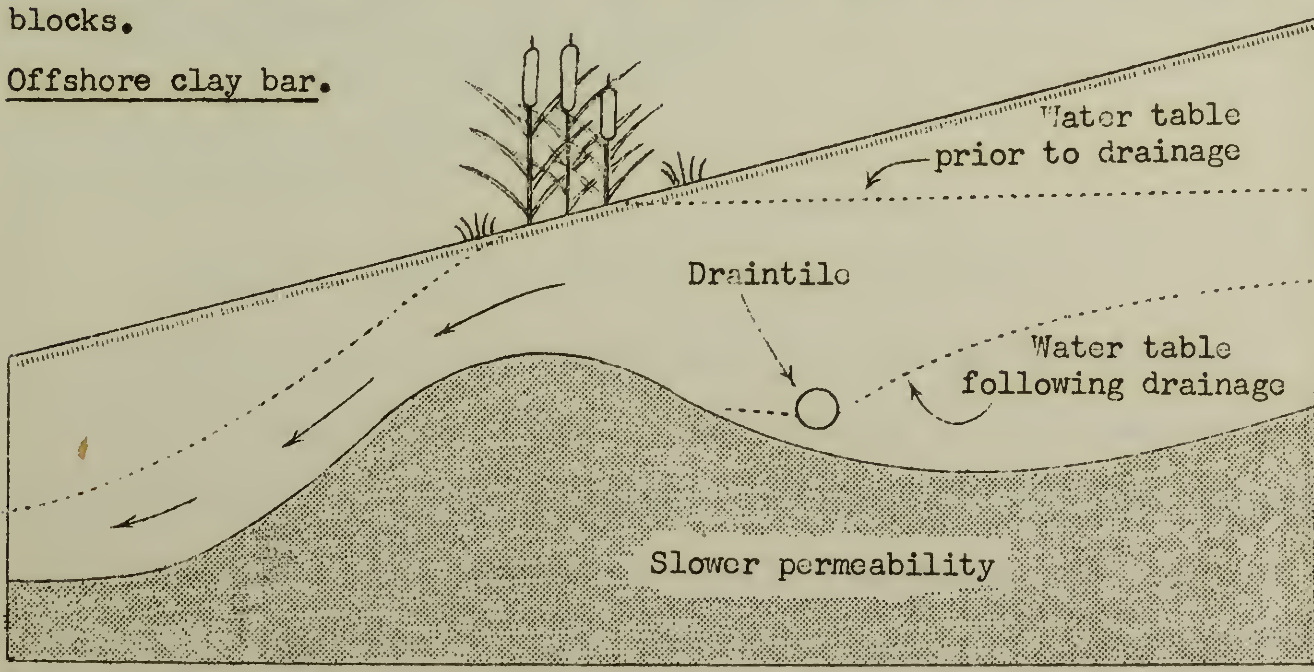


Figure 3. Offshore Clay Bar.

The underground offshore clay bar is relatively common in old lake areas. The underground dam or weir slowly forces the ground water to the surface or close enough to water-log the soil and cause a buildup of harmful saline or alkaline elements. In some areas the ground water comes to the surface as springs or seeps, flows over the surface and sinks back into the ground below the barrier.

This type of problem area can be drained by locating tile or open drains immediately upstream from the slowly permeable bar. The drain should be located relatively close to the bar to prevent as much ground water as possible from going under the drain.

Break in grade and a heavy soil cap.

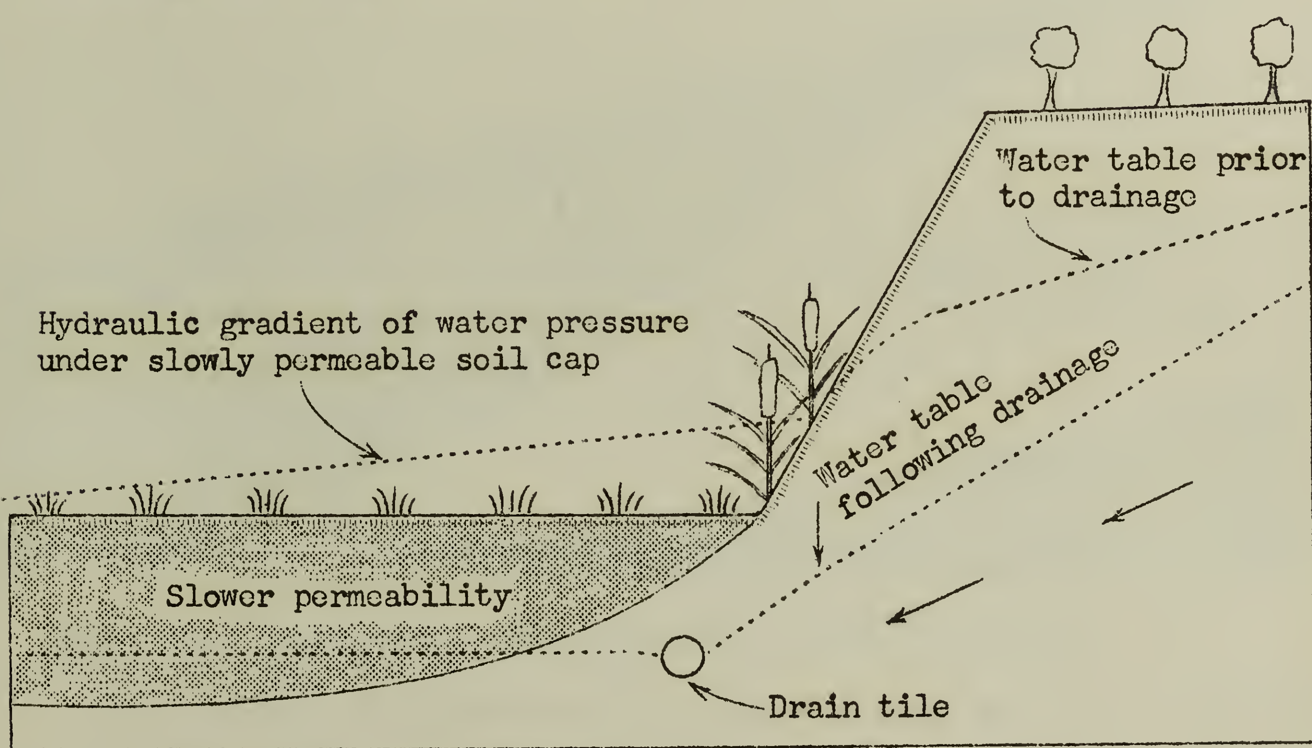


Figure 4. Break in grade and a heavy soil cap.

A break in grade in conjuction with a soil change is very common in benched farming areas. The heavy soil cap was possibly transported by streams or flash floods from higher areas and deposited over the more permeable soils. The heavy cap may be slowly permeable while the underlying soil, escarpment, and bench land may transmit water fairly rapidly.

The heavy soil cap acts as a dam and forces the ground water to the surface. Many times the soil cap confines the ground water and will cause a hydrostatic or artesian water pressure below the cap. A piezometer terminated below the slowly permeable cap will often show a hydrostatic pressure well above the ground surface.

This type of soil change problem area can best be drained by installing an interception drain below the toe of the impermeable stratum at the break in slope. The drain should be located in the more permeable soil stratum and as deep as economically feasible.

<u>Pinching off and deepening of permeable strata.</u>

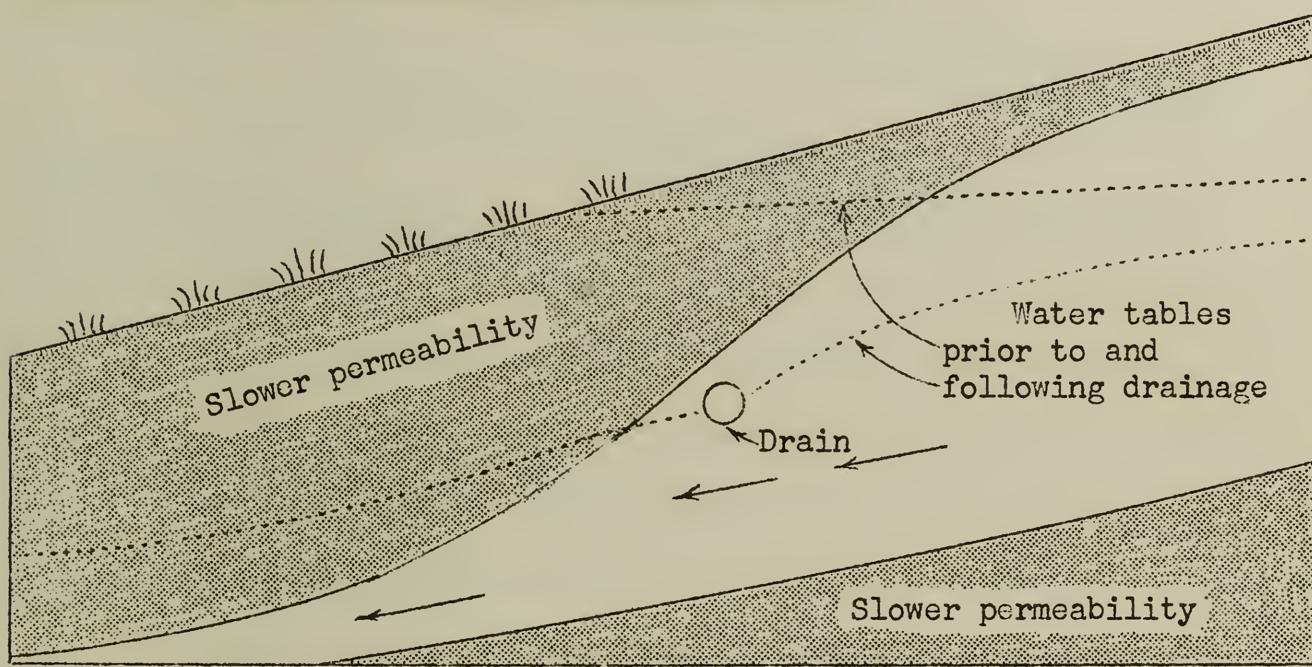


Figure 5. Pinching off and deepening of permeable strata.

The deepening and pinching off of permeable soil strata are relatively common. The resulting water-logged area may be fairly extensive. However, this type of soil change usually effects a smaller area.

The pinching off and deepening of the permeable strata reduces the area for underground water movement and slowly builds up the water table until it water-logs the surface.

This type can be drained by locating tile or open drains in the more permeable strata. The drain should be located fairly close to the heavy cap and as deep as feasible.

Subsurface drainage in conflict to natural surface drainage.

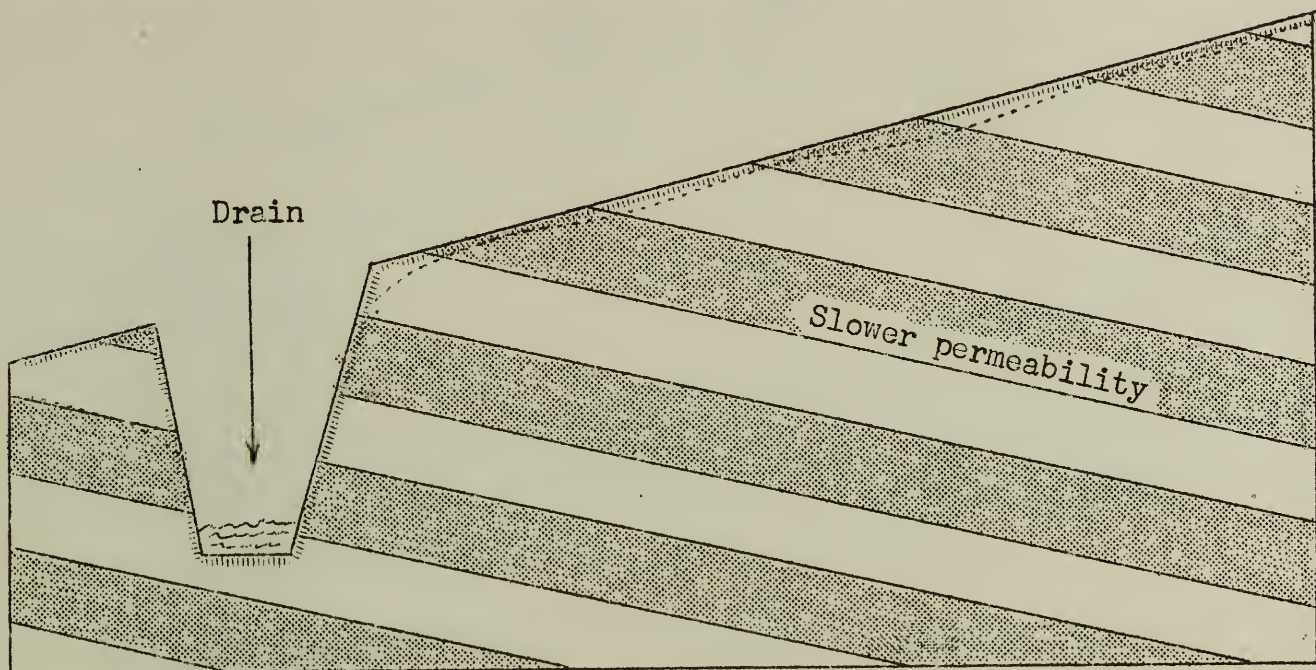


Figure 6. Subsurface drainage in conflict to natural surface drainage.

This type of soil change is not too common. Where it does occur, it may be a serious problem depending upon the thickness and permeabilities of the various strata. This profile was possibly formed by deposition from water flowing in one direction and the surface later eroded away to form the natural surface drainage in another direction.

Each slowly permeable strata acts as a dike and retards the ground water movements so that a water table may exist within a foot or two from the surface a few feet away from a 10 or 20 foot drain.

This type of problem is relatively hard to drain if the various strata are thin. Each layer acts as a small dam and makes drainage fairly costly. If the strata are thick, they may be drained individually by tile drainage laterals. Drainage work undertaken on this soil change type should be coupled with a high irrigation efficiency.

Old river or arroyo channel.

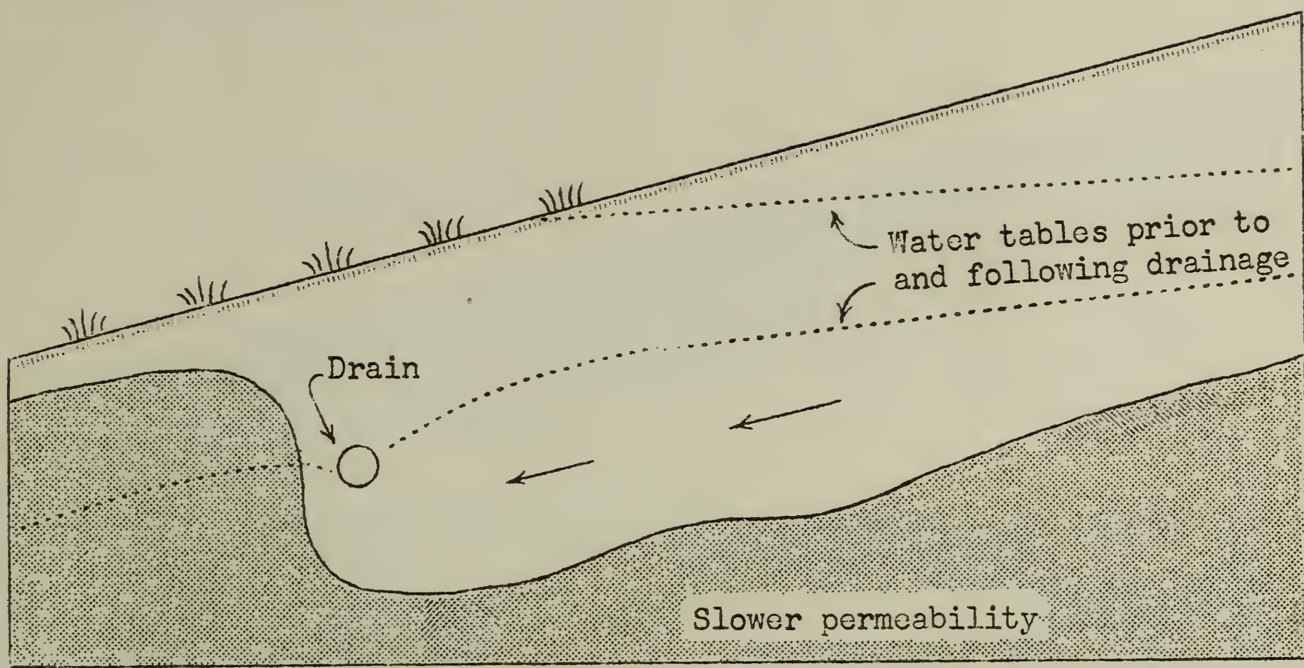


Figure 7. Old river or arroyo channel.

The old filled in arroyo or river channel is fairly common in meandering or braiding stream areas. The soils in the banks and bottom of old river channels are sometimes slowly permeable while the fill material may be coarse sand and gravel which is highly permeable.

The heavy bank acts as an underground dam and forces the ground water to the surface. Ground water may also flow laterally in the more permeable river channel fill and cause water-logging at a soil change farther down the old river channel.

This type can best be drained by locating tile or open drains immediately up stream from the slowly permeable river bank. An interception drain may also be required to intercept seepage water moving laterally along or down the old river or arroyo channel.

Buried alluvial fans.

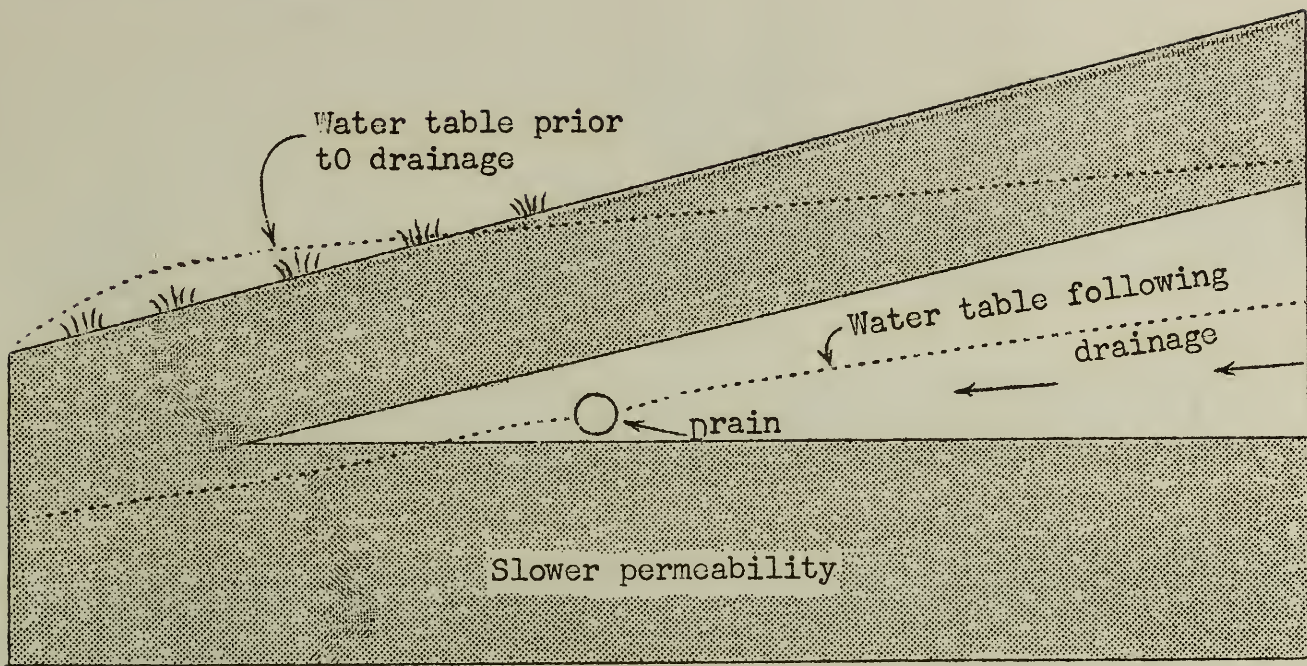
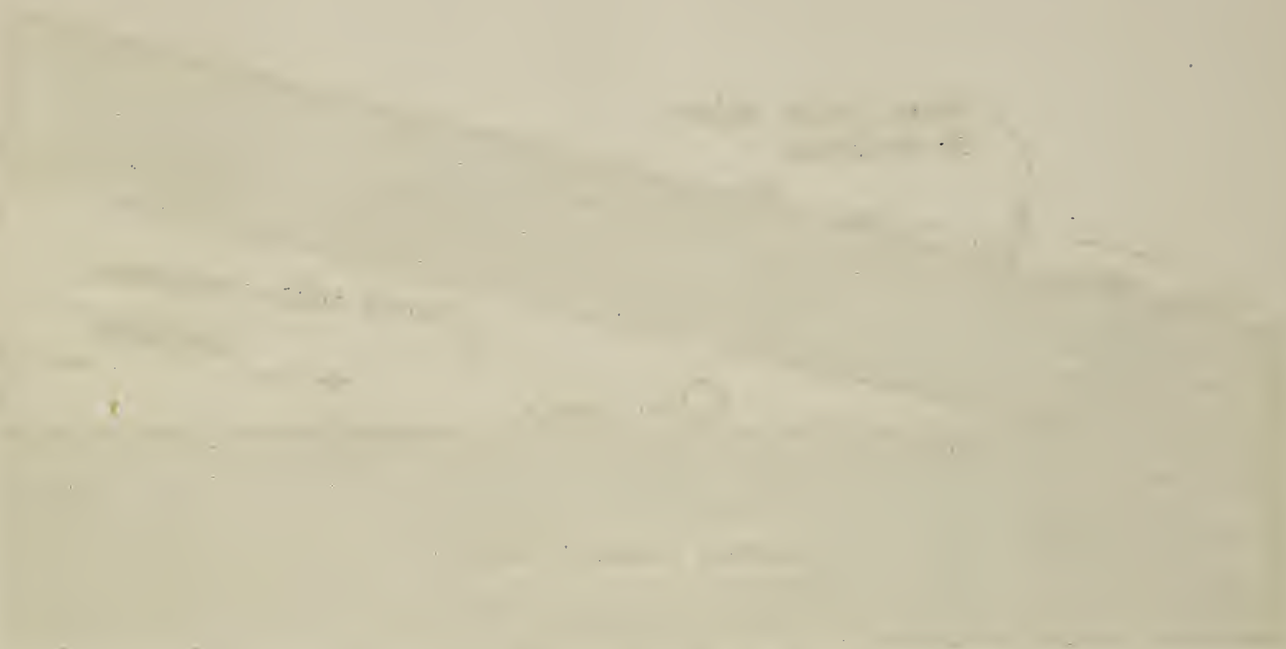


Figure 8. Buried alluvial fans.

The alluvial fan is very common along the edges of valleys. Fans are washed out from surrounding mountains by flash floods or high water. These fans are later covered with heavier soils and form permeable wedge-shaped sand and gravel strata.

Water pressure builds up in the fans and gradually creates a water-logged condition. The severity of the water-logging will depend upon the difference between the permeability of the fan and that of the retaining soils. In the more acute areas, the hydrostatic pressure at the lower end of the fan may be well above the ground surface.

These types of soil changes can best be drained by locating open or tile drains in the permeable fans. They should be installed as close to the end of the fan as feasible and still have an adequate aquifer to drain. This will prevent as much water as possible from going down slope in the fan and causing a lesser degree of water-logging below the drain.



Surfacing soil strata.

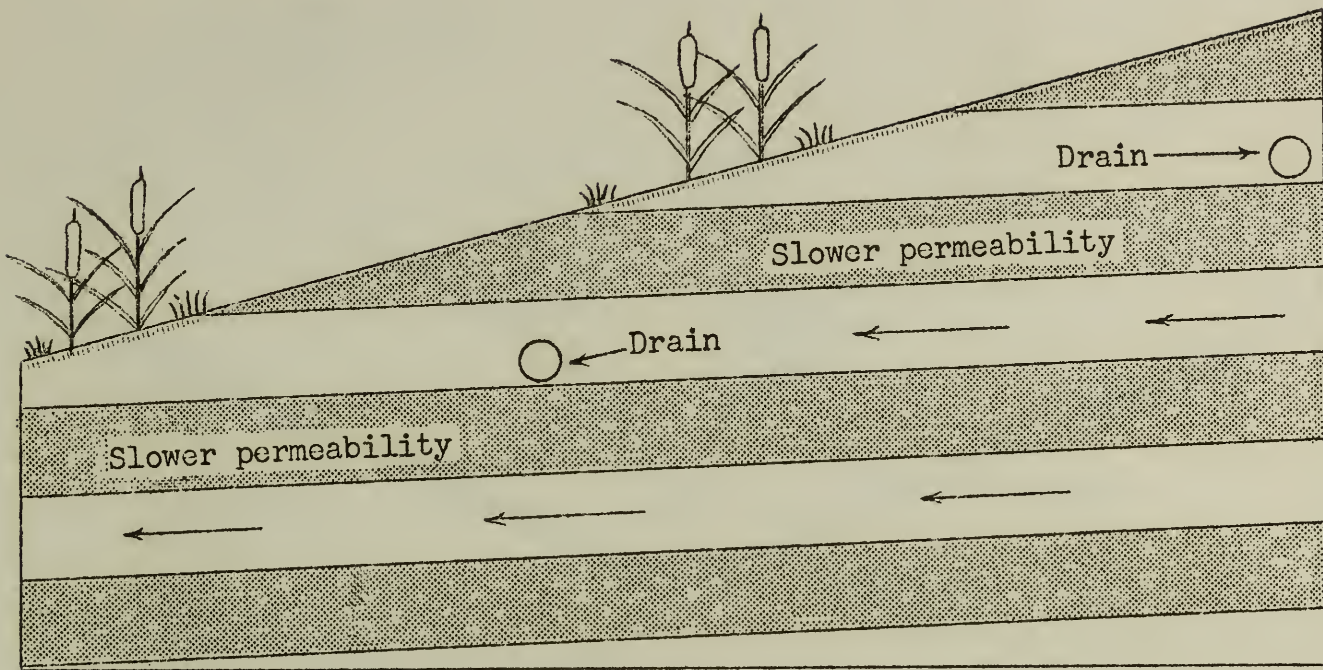


Figure 9. Surfacing soil strata.

The eroded surfacing soil strata are fairly common in old lake sediment soils. The soil strata were deposited in level layers and were eventually exposed by erosion of the soil surface. Some surfacing strata are also caused by fans and out-wash from surrounding hills. These surfacing fan strata were probably deposited under receding flood conditions and were not capped over by soil from later floods.

The ground water is brought to the surface on the heavier soil strata and a water-logged condition may result at the toe of each strata. The degree of water-logging will depend upon the difference in permeability of the alternate strata and the amount of water moving from above.

If the strata are relatively thick, individual tile or open drains may be used to drain individual strata. However, if the strata are fairly thin, a tile grid drainage system may be utilized as interception drains for a number of strata. The tile installation trench or open drain will cut the strata and remove the ground water before it gets to the surface.

Alkali soil change.

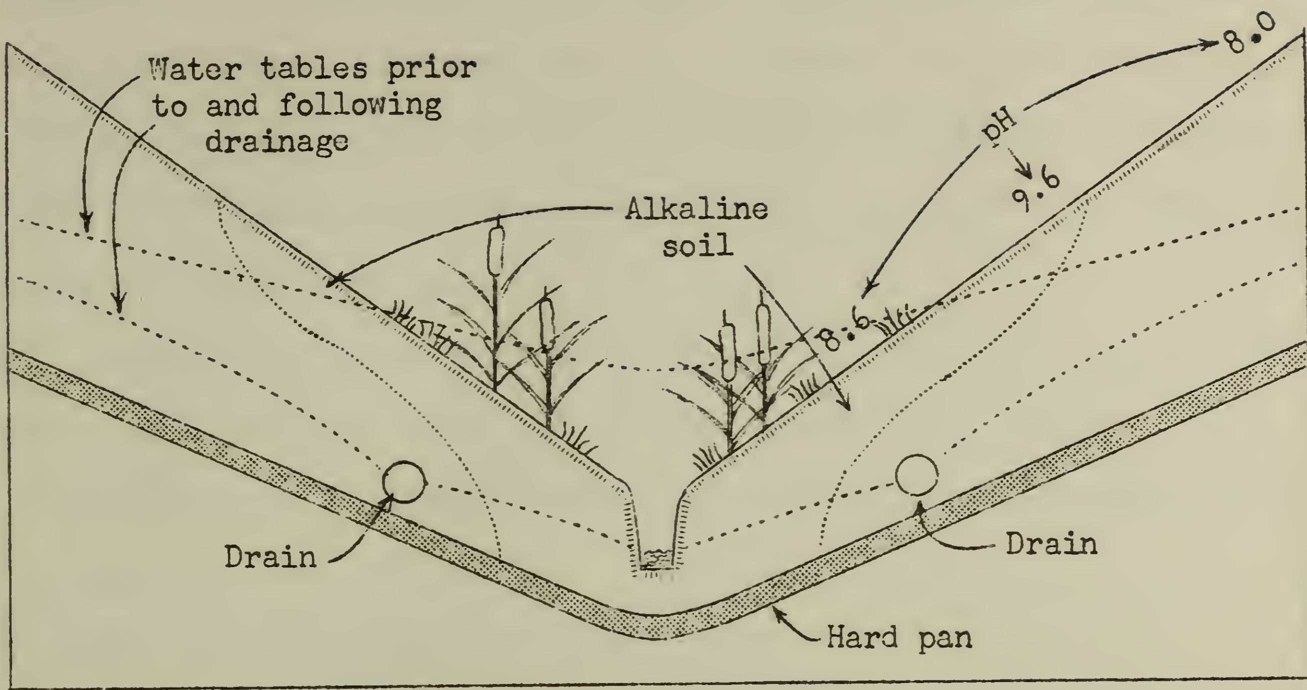
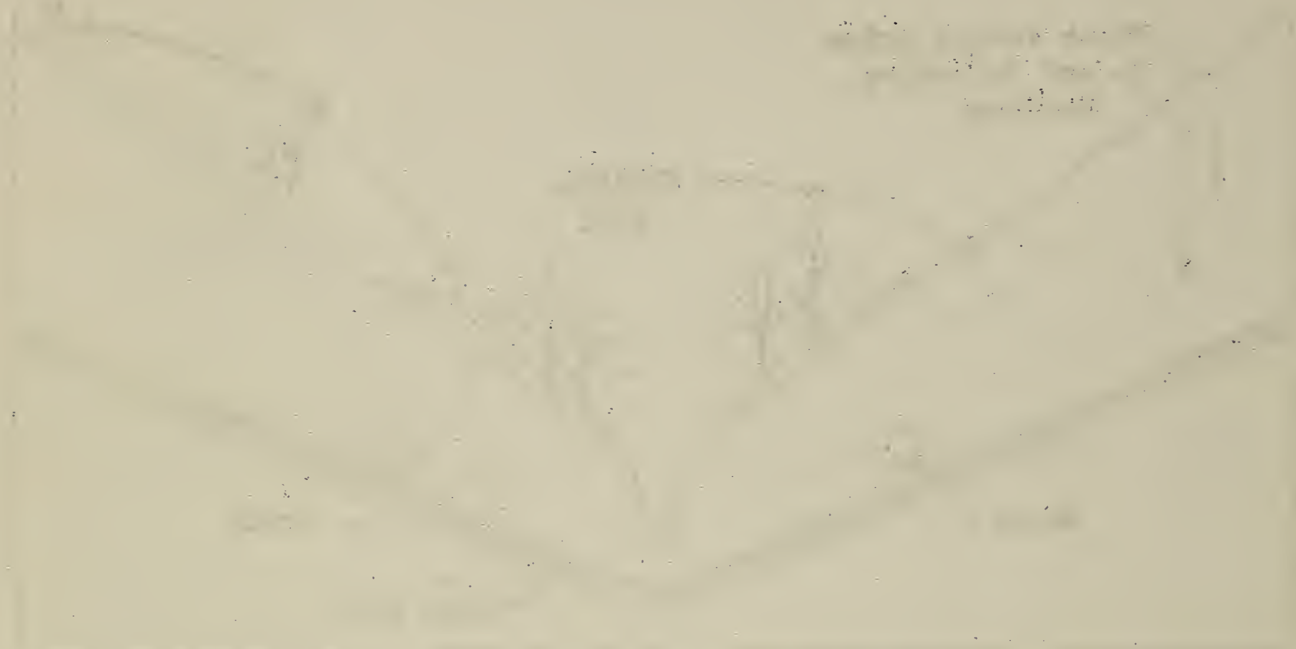


Figure 10. Alkali soil change.

Water-logging due to alkali accumulation is far more common than is generally thought. The general conception is that alkali is usually due to or a result of the water-logging rather than a major factor in causing the water-logging in some areas. If the water-logged line moves progressively up the slope from a few to 50 or more feet a year, it can generally be attributed to alkalizing of the soil. This alkalizing is generally greater at the surface; however, an eight or 10 foot profile may become so strongly alkaline that the permeability will decrease and cause an artificial soil change. This soil change due to alkali may be coupled with a natural soil change to cause the unique problem.

The problem is generally initiated from an increase in ground water from upslope. The present drain may be unable to adequately handle the flow of water and a seepage line developes above the drain. Capillary water and seepage slowly alkalizes this area, the permeability decreases and more cross-sectional area is needed to pass the same flow of water.



The seepage line moves up the slope to obtain this area and the water-logged alkaline area moves up the slope. If not reclaimed, these bad areas will move through farm land at an alarming rate. The alkaline soil on the surface acts as a cap and artesian pressure may build up below it. In some areas, this pressure builds up to five feet or more above the ground surface.

This type of soil block can be drained by installing tile or open interceptor drains upstream from the alkaline slowly permeable area. This will arrest the uphill movement and permit reclamation work on the alkaline area.

Artesian water logging with a surface cap.

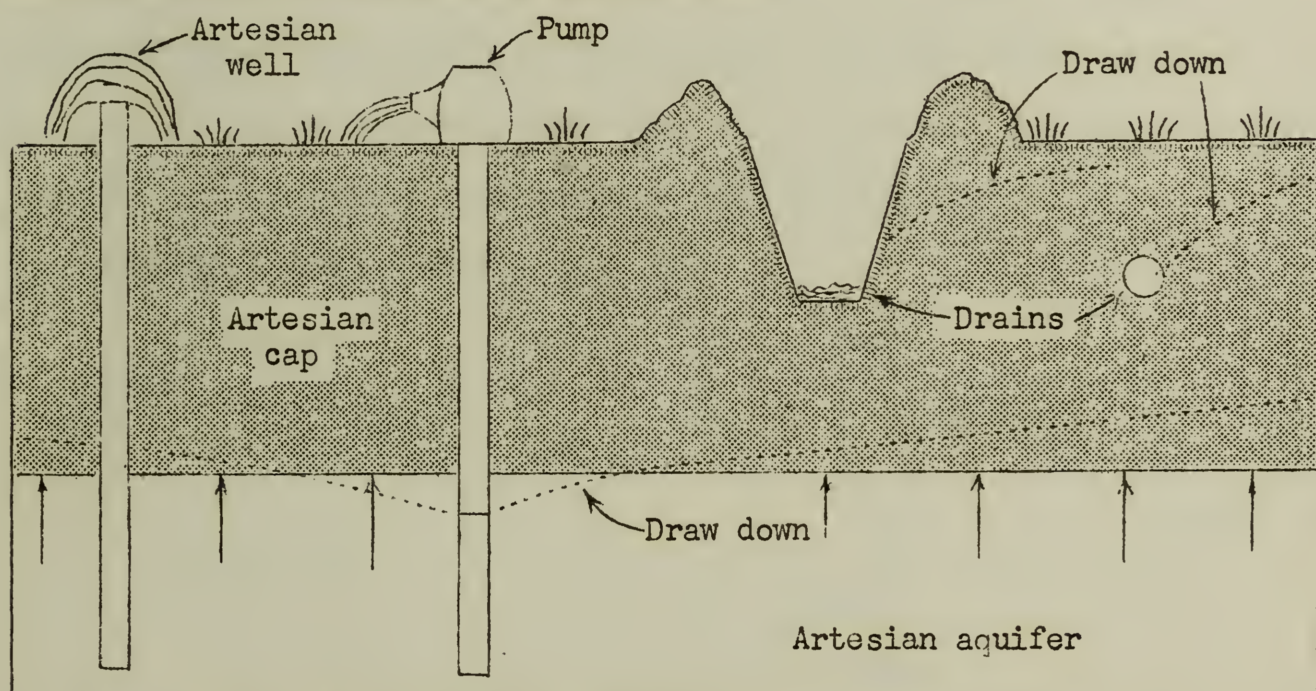


Figure 11. Artesian water-logging with a surface cap.

Water-logging due to artesian aquifers is fairly common throughout irrigated areas of the West. Water-logging in these areas may not be entirely due to the artesian aquifer, but a combination of artesian water, over-irrigation and seepage from adjacent lands and ditches. The example, (Figure 11) has a slowly permeable soil cap extending to the ground surface which makes surface drainage rather costly.

The artesian water slowly moves to the surface through the retaining soil cap and water-logging results. In some areas, the water-logging is accompanied by saline and alkaline deposits and the area eventually goes out of production. An acute water-logging condition can develop in these areas when the physical factors are favorable. In some instances artesian pressure exceeds forty feet above the ground surface.

If the artesian cap extends to the surface and is fairly impermeable, it may prove economically unfeasible to drain the soil with tile or open drains. Surface drains may have to be installed very close together to adequately drain the area. Pumping from the artesian aquifer may prove more economical. The hydrostatic pressure can be greatly reduced and eliminate water from moving to the surface. This will allow natural drainage to aid in removing water from other sources. Open or tile drains may also be required to adequately reclaim the area.

<u>Artesian water logging with a deep cap.</u>

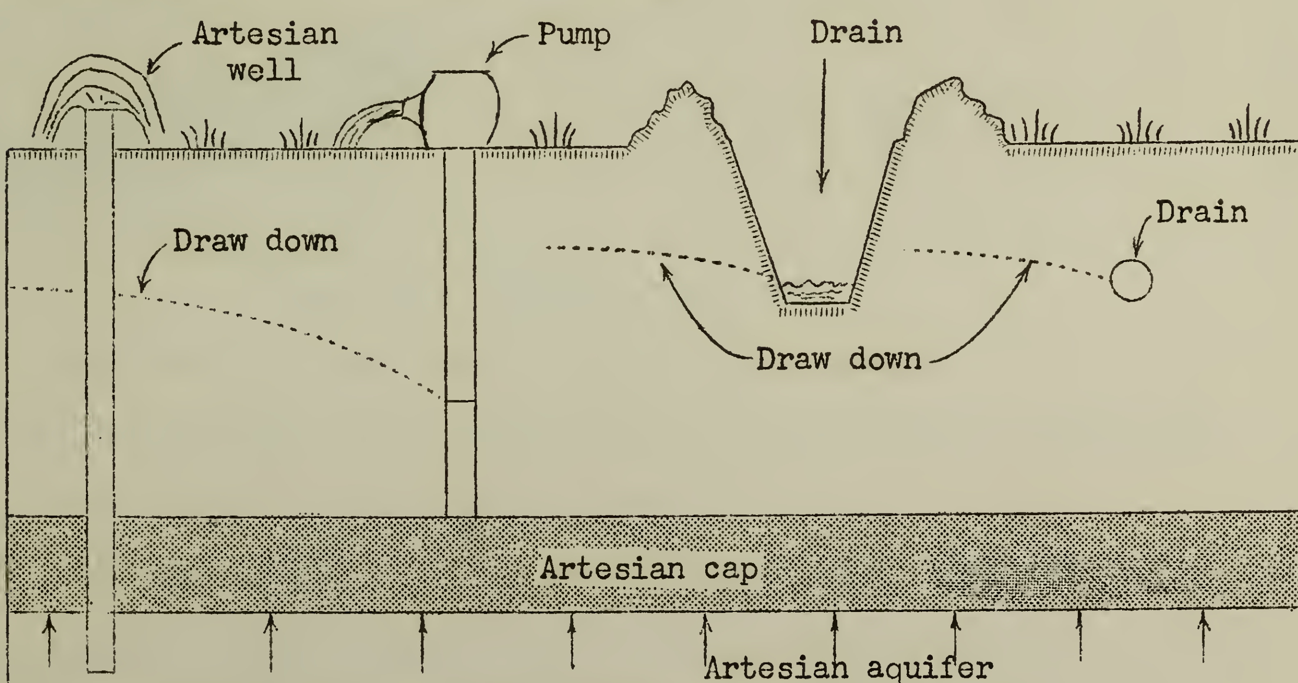


Figure 12. Artesian water-logging with a deep cap.

In this example water-logging is probably due to water from several sources. Artesian water along with seepage from adjacent land, irrigation

ditches and over-irrigation usually aggregate to cause the drainage problem.

The artesian water moves to the surface and gradually water-logs the area. Alkali or saline elements can be built up as in Figure 11.

If the aquifer above the cap is fairly deep and permeable, it may be feasible to remove the surface water with open drains, tile drains, or pumps. The cap can be used to advantage to retain the artesian water and the surface drains will pick up and remove any water that comes through.

Artesian water block.

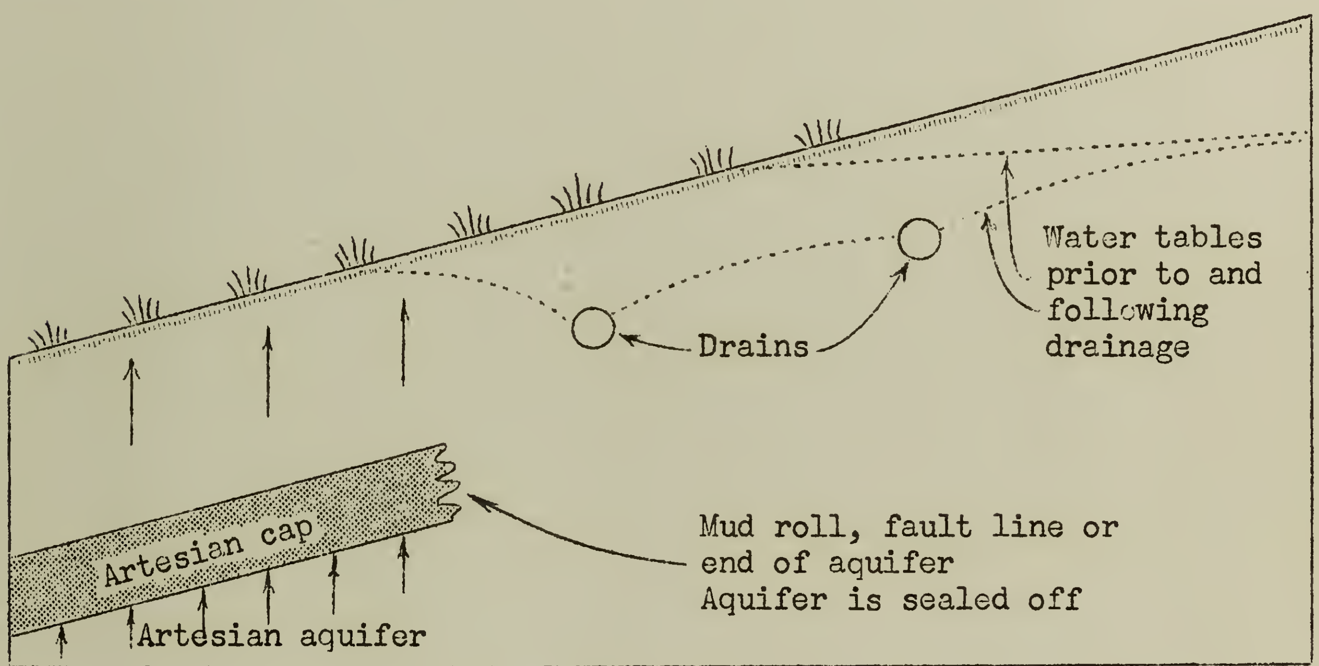


Figure 13. Artesian water dam.

The artesian water block is rather rare. However, in the areas where it does occur, it may water-log an area for several miles above the termination of the artesian aquifer.

The artesian water rising to the surface water-logs the soil profile and forms an underground water dam or mound. Ground water moving down from land upslope is held back by the water block and slowly builds to the surface.

This type of problem can be reclaimed by installing drains upstream from the water block. If the artesian water-logged lands were drained, natural drainage may take care of the greater part of the problem.

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